T-N-271
Filing Code ~~6601~~ 6600

Date Issued June 1975

TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

HABITAT MANAGEMENT SERIES FOR UNIQUE OR ENDANGERED SPECIES

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Report No. 15

Merlin
Falco columbarius

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FOREWORD

This Technical Note series on wildlife is designed to provide a literature review and summary of current knowledge pertaining to endangered and other wildlife species occurring on public lands. We in the Bureau of Land Management have recognized the need for basic wildlife information in order to do an effective job in land-use planning. Sound planning must identify the negative aspects as well as the positive benefits of any proposed land management decision or program. It is our hope, too, that this series will also prove useful to others--be they land managers, students, researchers or interested citizens.

Ernest Berklund

Director
Bureau of Land Management
Department of the Interior

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SPECIES DESCRIPTION

The merlin, or pigeon hawk, occurs throughout much of the northern hemisphere. Brown and Amadon (1968) name eight races worldwide. In North America, three distinct geographic races of this small, swift-flying falcon breed in three ecologically distinct regions: the taiga, Pacific coastal forest, and prairie-parkland. Although the American Ornithologist's Union (A.O.U.) Checklist (1957) recognizes four subspecies, Temple (1972a) and Brown and Amadon (1968) recognize only three of these forms, corresponding with the above-mentioned breeding populations. In this report, I follow Temple's taxonomic revision.

Falco columbarius columbarius includes all North American taiga-breeding birds (merging the A.O.U. subspecies columbarius and bendirei, forms similar in phenotype and ecology). Falco columbarius suckleyi breeds in the Pacific coastal forest. And F. c. richardsonii refers to the prairie-parkland merlins. Although the A.O.U. does not recognize common names for subspecies, to avoid constant repetition of Latin subspecifics I will refer to the three subspecies above as the taiga merlin, black merlin, and Richardson's merlin, respectively.

Merlins exhibit the typical falcon silhouette--long, pointed wings and a longish tail. They are much smaller than the large falcons--about 25 to 34 centimeters long, with a wingspread of about 60 centimeters (Peterson, 1961). Like most other falconiforms, female merlins surpass males in size. Despite subspecific size variations, the degree of sexual size dimorphism remains constant in all populations. Females average larger than males in most measurements--about 20 millimeters longer in the wing (averaging 213.1 mm versus 192.2 mm), and about 11 mm longer in the tail (averaging 128.57 mm versus 117.8 mm) (pooled data for all North American merlins; Temple, 1972a). Males have a proportionately wider wing than females (Temple, 1970). Adult and immature merlins also differ in size: juveniles have longer flight feathers than adults, thus affording young birds lighter wing loading while they develop their powers of flight. (Wing loading is the ratio of weight to wing surface area.)

Five male taiga merlins averaged 162 grams in weight (Brown and Amadon, 1968). Two taiga females weighed 200 grams and about 227 grams (Swartz, 1972). In a group of Newfoundland and Atlantic Coast migrants, 47 males averaged 159 grams, and 69 females averaged 218 grams (Temple, personal communication). Female Richardson's merlins weigh about 227 grams (Oliphant, 1974). A wintering female black merlin weighed 218 grams (Slipp, 1942).

Merlins display marked sexual dichromatism, particularly in adult plumage. Subspecies vary, but in general, adult males (for a "typical" adult male F. c. columbarius, see Figure One) have slaty blue-gray dorsal and crown plumage, varying from light gray to near-black, and marked by a mottled buff nuchal collar and the distinct black shaft stripes of individual feathers. Breast, flanks, and abdomen are buffy, boldly streaked vertically with cinnamon to black, with the widest streaks on the flanks. Few streaks mark the clear buff-colored throat and sides of the head. Both immature and adult merlins, of both sexes, possess dark tails distinctly banded with gray or buff. Merlins lack the bold moustachial stripe characteristic of many other falcons. The bill is bluish, the eye very dark brown; cere, eyelid, tarsi, and toes are yellow, and the claws black.

Adult females differ from adult males primarily in the dark brownish color of their dorsal plumage, contrasting with the slate-blue of the male. This single distinction suffices for separation of adults in the field. Streaking below tends toward brown, on a lighter background than the male.

Immature merlins of both sexes closely resemble adult females in dorsal coloration. The rump and upper tail coverts of the adult female, however, are slate-brown in contrast to the dark brown of the back, whereas the rump and upper tail coverts of immatures are the same shade of brown as the back. Many immatures have more greenish soft parts than the rich yellows of most adults. Immature males and females differ in the color of the light tail bands, especially in the central part of their tail feathers. Immature males have light gray bands; immature females have buffy bands. Merlins acquire definitive adult plumage with their first prebasic molt, which lasts from April until September of the calendar year following their hatching year. These falcons continue to molt once each year, during these same months, throughout their lives, although the female may molt before the male when breeding (Temple, 1972a, 1972b, and pers. comm.; Bent, 1938; Brown and Amadon, 1968; Friedmann, 1950; Peterson, 1961; Laing, 1938; Eyre and Paul, 1973; Oliphant, 1974).

At hatching, creamy-white and pure white down covers the young, except for the bare abdomen. A second, coarser smoke-gray down replaces this first plumage. By the age of 18 days, primaries and tail rectrices have burst their sheaths. By 25 days the young birds are fully feathered (Bent, 1938; Brown and Amadon, 1968; Friedmann, 1950; Fox, 1964).

Figure 1: Adult male Falco columbarius columbarius

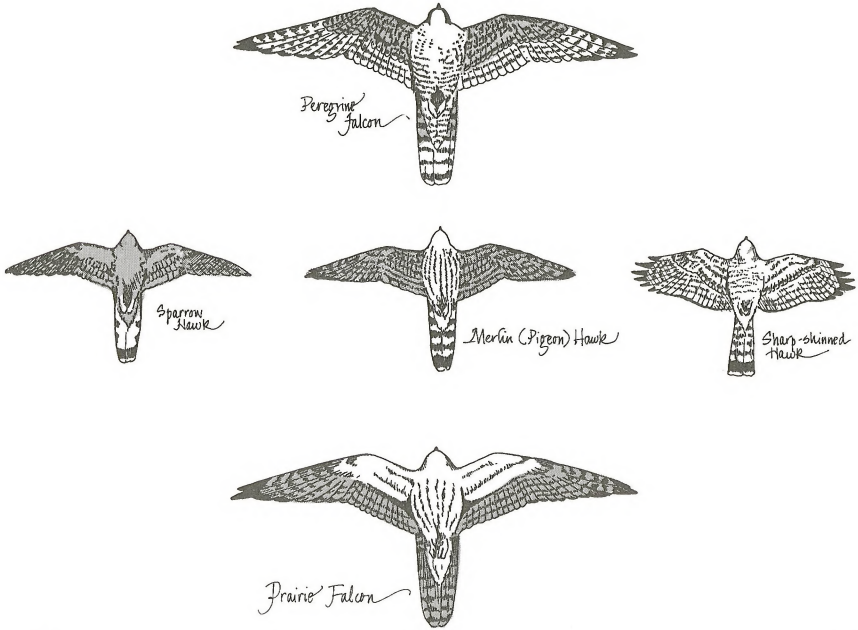


Figure 2: Flight [illegible]houttes

Merlins vary considerably across their range in both size and plumage characters. Richardson's merlins have longer wings and tails, on the average, and lighter wing loading, than other North American merlins. Presumably, this proves a selective advantage for frequent long flights in their open prairie-parkland habitat. Black merlins, inhabiting the densest habitat of the three subspecies, have the heaviest wing loading. Taiga populations are intermediate (Temple, 1972a).

Plumage coloration provides one of the most obvious means for separating subspecies. Richardson's merlins (prairie-parkland breeders) are lightest in color, black merlins (humid coastal forest breeders) are darkest, and taiga merlins intermediate. Black merlins derive their common name from the extreme darkness of their dorsal plumage. Richardson's merlins differ from other populations in having five light tail bands (these figures do not include the terminal light band). Black merlins usually have four light tail bands, but extreme saturation of tail rectrices by dark pigment often eliminates one of these, creating an appearance of only three bands. Taiga merlins nearly always have four light bands. The uppermost light band in all subspecies may be obscured by tail coverts. Crown streaking and primary barring also show patterns of geographic variation (Temple, 1972a).

Merlins earn their second widely-used name--the pigeon hawk--through similarity of size and flight, rather than from any preference on the merlin's part for consuming domestic pigeons, or rock doves (Columba livia). Falconers have flown merlins for centuries--particularly at small birds such as larks (Alaudidae). Merlins suggest miniature peregrine falcons (Falco peregrinus) in their slate-blue coloration and swift, direct flight. Even in normal flight they exceed speeds of 20 meters/second (45 miles per hour). In their ability to twist and turn while pursuing quarry, they surpass other falcons, and challenge the skill of accipiters. Like other falcons, merlins attain peak speeds when stooping at prey--at perhaps 27 to 40 meters per second (60 to 90 mph). Merlins soar infrequently (Williams and Matteson, 1947; Fox, 1964; Brown and Amadon, 1968). Fox (1964) describes a curious hovering flight, most characteristic of fledglings begging food, with wings extended and tail spread, flapping the distal portions of the wing like a kingbird (Tyrannus sp.).

Observers in the field may confuse merlins with sharp-shinned hawks (Accipiter striatus), but the falcon's pointed wings and direct flight with deep, regular wingbeats serve to distinguish the two. Smaller size and lack of moustachial stripes should easily separate merlins from larger falcons. Lack of rufous

on tail or back, along with indistinct facial markings, distinguish merlins from North America's other small falcon, the American kestrel (Falco sparverius) (see Figure Two). Peterson (1961) emphasizes dark dorsal coloration and the distinctly banded tail as helpful field marks.

DISTRIBUTION

Merlins occur at some time of year in every province of Canada and every state of the continental United States. Although most wintering birds migrate south, some merlins remain near their breeding grounds all year. Breeding ranges for the three North American merlin subspecies are considerably more restricted, nearly coinciding with the limits of the boreal forest, plus the northern Pacific coastal forest and northern Great Plains (see Figure Three).

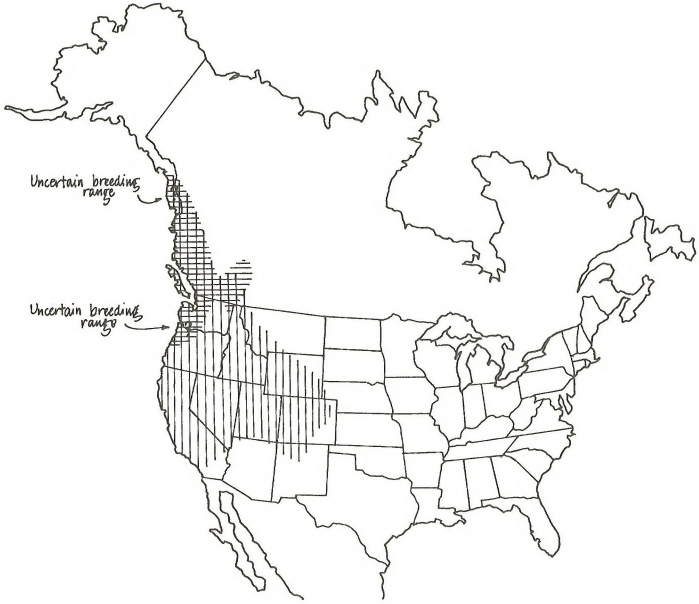
Falco columbarius columbarius, the taiga merlin, breeds in the boreal forest from tree-limit in northern Canada, from Newfoundland west to northwestern Alaska, south to south-central Alaska through British Columbia east of the Cascade and Coast Ranges to north-central and eastern Washington and Oregon, and (perhaps) western Montana (Missoula County). The boundary then swings north into Canada west of the prairie-parkland, east across the taiga, then south into the northern parts of North Dakota, Minnesota, Michigan, and New England (A.O.U. Checklist, 1957; Ellis, 1974; Brown and Amadon, 1968; Jewett, et al., 1953; Friedmann, 1950). Taiga merlins occasionally breed as far south as northern California, Idaho (Bingham County), southwestern Wyoming (Fort Bridger), Colorado (Summit County, Grand County, and Fort Lewis--although it seems more likely that these are actually misidentified Richardson's merlins), and the Wasatch Mountains of Utah (A.O.U. Checklist, 1957; Williams and Matteson, 1947; Bent, 1938; Bailey and Niedrach, 1965; Wolfe, 1946). Most taiga merlins migrate south in autumn, wintering across the western states, south to the southern states, through Mexico to Central America and the West Indies, and as far as Venezuela, Ecuador, and northern Peru (A.O.U. Checklist, 1957).

Richardson's merlin breeds in the prairie-parkland of the northern Great Plains from the fringes of the boreal forest (northeast of Prince Albert, Saskatchewan; Oliphant, personal communication) through the Canadian prairie provinces (Alberta, Saskatchewan, and Manitoba) south to northern Montana (Lewis and Clark, Valley, Cascade, Toole, and probably Choteau Counties), northern North Dakota, and South Dakota (A.O.U. Checklist, 1957; Ellis, 1974; Brown and Amadon, 1968; Hunter, 1967). Richardson's merlins have also nested in eastern Wyoming, in Albany and Weston Counties (Fox, 1964). Falco

Figure 3: Distribution of the merlin in North America a. Falco columbarius columbarius

Approximate breeding range

Approximate winter range



b. Falco columbarius suckleyi

c. Falco columbarius richardsonii

columbarius richardsonii winters south through Wyoming and Colorado to California (where it is uncommon), northern Mexico, and west Texas (Friedmann, 1950). Most migrant Richardson's merlins reportedly winter in Wyoming and Colorado (Fox, 1964).

The black merlin, F. c. suckleyi, breeds in the moist coastal forests of western British Columbia, Vancouver Island, the Queen Charlotte Islands, and the coastal islands of southeastern Alaska, inland to the Okanagan Valley and the town of Blue River, and north to Atlin and (probably) the upper Yukon River drainage (Bent, 1938; Munro, 1946; Laing, 1935; Sutton, 1935; Friedmann, 1950; Swarth, 1935). No certain breeding records exist for the black merlin within the United States. Bent (1938) mentions a possible nesting at Fort Klamath, Oregon, another in the Puyallup River valley of Washington, and a set of eggs (suckleyi or columbarius?) collected at Sitka, Alaska in 1887. Black merlins may have nested at Bumping Lake, Yakima County, Washington (Jewett, et al., 1953). Jewett (1939) observed what appeared to be a family of recently fledged black merlins in early August in Deschutes County, Oregon--well east of the Cascades. Gabrielson and Lincoln (1959) report an adult female black merlin taken on Sergief Island, north of Wrangell, Alaska, on August 19. An extremely dark male merlin was taken as a nestling by Pat Redig (of the University of Minnesota) in northern Minnesota in 1974 (Oliphant, personal communication). Wintering black merlins remain chiefly in the coastal area southward through Washington, Oregon, western Montana (Ellis, personal communication), and central California (Unglish, 1934), to southern California (van Rossem, 1934; Miller, 1941; Spaulding, 1947), but also wander southwestward as far as New Mexico (Jewett, 1944) and Colorado (Bailey, 1942) and north to coastal Alaska (Friedmann, 1950; A.O.U. Checklist, 1957). Although forty years have passed since Swarth (1934, 1935) lamented the near-complete lack of nesting data for this subspecies, even today we know little more of its habits and range.

STATUS AND POPULATION TREND

As a species, merlins are not endangered. But the three North American subspecies vary dramatically in status.

Taiga and black merlins are probably not yet in any serious population trouble. Both subspecies breed in environments not highly altered by man (Temple, personal communication.; Fyfe, personal communication). Swartz (personal communication) found taiga merlins breeding in interior Alaska with good productivity and in normal density, which is to say, not very abundant. Migration counts in Alaska in 1968 indicated merlin populations seemed to be holding their own (Adolphson, 1969). Richardson's merlins, however, have suffered population declines.

All three subspecies carry high levels of chlorinated hydrocarbon residues. For F. c. columbarius and suckleyi, lowering of reproductivity due to pesticide poisoning is significant, but slight. Richardson's merlin, in contrast, has suffered massive reproductive failure over most of its range--which constitutes the most contaminated of all North American merlin habitats (Temple, personal communication). Fox (1971) documented a 43% decrease in hatching success since 1950 for Richardson's merlins nesting in the Great Plains grasslands, corresponding with a marked decrease in eggshell weight.

Not only has productivity declined, but the Richardson's breeding range has contracted rapidly during the past 20 years. Two factors have reduced the area of suitable breeding habitat. First, Richardson's merlins depend on grassland birds for food. As areas of native grassland shrink under the pressures of intensive cultivation, Richardson's merlin populations likewise shrink. Second, these merlins nest exclusively in trees. Without suitable nest sites, they cannot reproduce. Where native grassland and nest sites persist, merlins seem to be maintaining their populations, or even slowly increasing (Fyfe, personal communication). Oliphant (personal communication) considers the Richardson's merlin common in the Saskatoon, Saskatchewan area, with good production of young (4-5 fledged in many nests). However, on Saskatchewan Christmas counts, wintering merlins were down 43% during 1964-1967, compared to 1957-1963, and down 55% during the same time period in the number of locations where the bird was sighted (Fox, 1971). Recent Saskatchewan Christmas counts have been high, six birds seen in Saskatoon alone in 1973-1974 (Oliphant, personal communication). Temple and Fox both regard Richardson's merlin as endangered (Temple, personal communication; Fyfe, personal communication; Fox, personal communication).

Migration counts at Duluth, Minnesota, show that while total raptors observed increased by 87% during 1960-1967 (over 1935-1942), merlins decreased by 83%. Increased late-season observations might bias these data somewhat. At Hawk Mt., Pennsylvania, merlin counts for these same years were down 13% while total raptors increased 9% (Fox, 1971). Duluth birds probably include migrants from the eastern edge of the Rockies to central Ontario--central taiga merlins, with perhaps some Richardson's. Hawk Mt. birds breed along the Atlantic Coast and in Newfoundland, though Hawk Mt. is not on a major merlin migration route (Temple, personal communication). Variation in merlin counts may reflect the health of merlin populations nesting in the differing source areas.

Ellis (1974) reported eight positive breeding records for merlins in Montana. Productivity was high for successful nests, but three of seven nests with eggs failed--all Richardson's merlins. Merlins have probably long been established in Montana, but are so rare as to nearly have gone undetected. Ellis believes the Montana population may be declining.

Although populations of taiga and black merlins seem to be only slightly declining on a continent-wide basis, biologists should watch them closely. As the taiga of northern Canada and Alaska grows ever more civilized while man develops its resources, merlins there may fail to reproduce successfully.

One note of optimism may be found in work by Oliphant (1974) in Saskatchewan. He described eight nesting attempts by merlins from 1971-1974 within the urban environment of Saskatoon. These merlins successfully fledged young in the constant presence of thousands of people, dogs, cats, cars, trucks, etc. Their diet consisted almost entirely of house sparrows (Passer domesticus), rather than native grassland birds. Fox (personal communication) reports other consistently successful merlin nestings in Canadian prairie cities.

LIFE HISTORY

Daily activity patterns

Merlins are strictly diurnal birds. When nesting, the male leaves his roost to hunt early in the morning, usually returning quickly with prey for the female and young. Taylor (1914) noted two periods of hunting and feeding activity during the day for merlins nesting in Britain: daybreak to 11 A.M. and 4 P.M. to dusk. Selous (1915) found merlins in Iceland following a similar activity pattern, with the early and late periods shortened, and a third hunting and feeding period added from about 1 P.M. to 4 P.M.

On the Minnesota-Ontario border, Craighead and Craighead (1940) counted three feedings of young merlins between 9 A.M. and 5 P.M. These feedings usually included an early morning and late evening hunt. Lawrence (1949) counted 1 to 2 feedings in 3 to 5 hours in Ontario. Breckinridge and Errington (1938), however, observed a nest of half-grown young in northern Minnesota to which the adults brought food 10 times during the day.

Merlins hunt at twilight, at least occasionally. Lawrence (1949) noted this behavior in a nesting male, while Johnson and Coble (1967) observed merlins actively hunting as late as

9:30 P.M. in Isle Royale National Park, Michigan. Bats made up part of these merlins' diet, which presumably accounts for such late-evening hunting.

In migration, taiga merlins feed early in the day (Bent, 1938), and fly more in the afternoon than do other hawks migrating along the east coast (Allen and Peterson, 1936).

Food habits

Merlins survive on a diet of birds almost exclusively. Brown and Amadon (1968) summarize the diet of the species, worldwide, as 80% birds, 5% mammals, and 15% insects. Merlins also have consumed toads, lizards, and snakes (Bent, 1938).

Birds taken by merlins range in size from small sparrows (Fringillidae) and wood warblers (Parulidae), to teal (Anas sp.), rock doves, and ptarmigan (Lagopus sp.) (Bent, 1938). Fyfe (personal communication) has not recorded a single mammal in extensive food data for Canadian-breeding taiga and Richardson's merlins. Lawrence (1949) estimated that one breeding pair of merlins require 450 birds to support themselves and their young during the 2½-month nesting season. Brown and Amadon (1968) think this an excessively high estimate, suggesting that 3 to 5 kills a day may suffice for the female and three young.

Males evidently prey on smaller species than females, reflecting the smaller size of the male falcon. At one Newfoundland nest, the male taiga merlin captured all prey during the first week after hatching, while the female constantly brooded the nestlings. Of 19 prey items brought to the nest during this week, 79% were species of birds weighing less than 50 g. From the end of this first week until fledging, 27% of 109 food items weighed under 50 g. During this period the female resumed hunting regularly, and the larger species are presumably her prey (Temple, 1972b). Alternately, merlins may take larger prey species as food demands of their fast-growing young increase (Lawrence, 1949).

Of 136 prey remains at nests of Newfoundland-breeding taiga merlins, three species comprised over half the merlins' diet: gray jay (Perisoreus canadensis), American robin (Turdus migratorius), and Savannah sparrow (Passerculus sandwichensis) (Temple, 1972c). Merlins, like other raptors, will concentrate on a few prey species if these species prove easy to capture owing to local abundance or behavior. Oliphant (1974) found that merlins breeding in urban Saskatoon, Saskatchewan, consumed primarily house sparrows, plus a few cedar waxwings (Bombycilla cedrorum), tree swallows (Iridoprocne bicolor), and

horned larks (Eremophila alpestris); house sparrows accounted for over 90% of prey at one nest. Wintering merlins in Alberta cities fed largely on Bohemian waxwings (Bombycilla garrulus) and sparrows (Fyfe, personal communication). A pair of Richardson's merlins breeding on the Saskatchewan prairie survived on a diet of 53.5% horned larks, 13.3% brown-headed cowbirds (Molothrus ater), 6.7% vesper sparrows (Pooecetes gramineus), 6.7% song sparrows (Melospiza melodia), 6.7% Baird's sparrows (Ammodramus bairdii), and 13.6% chestnut-collared longspurs (Calcarius ornatus). With the exception of Baird's sparrows, these species all were abundant in the merlins' hunting territory (Fox, 1964).

In Isle Royale National Park, a pair of breeding taiga merlins consumed primarily birds, including warblers, sparrows and crossbills, red-breasted nuthatch (Sitta canadensis), common nighthawk (Chordeiles minor), common flicker (Colaptes auratus), and an unidentified member of the Rallidae. These merlins also preyed on bats (red bats, Lasiurus borealis, and Myotis sp.), dragonflies (Odonata), and beetles (Coleoptera) (Johnson and Coble, 1967). Taiga merlins migrating past Cape May, New Jersey, also had consumed red bats (Allen and Peterson, 1936). The few other mammals recorded in merlin diets include pocket gophers (Geomyidae), squirrels (Sciuridae), and field mice (Microtus sp.) (Bent, 1938; Allen and Peterson, 1936; Burleigh, 1972).

During summer and fall, insects increase in importance in the merlin diet. Young falcons, especially, seem to rely on insects for food as they develop their predatory skills (Williams and Matteson, 1947; Eyre and Paul, 1973; Lawrence, 1949).

Jewett (1939) described two immature female black merlins in Oregon which had eaten nothing but black ground beetles (Carabidae). Other arthropods in merlin diets include caterpillars, butterflies, and moths (Lepidoptera), grasshoppers and crickets (Orthoptera), spiders (Araneida), scorpions (Scorpionida), and crayfish (Astacus and Cambarus sp.) (Bent, 1938; Allen and Peterson, 1936; Fox, 1964).

Dragonflies, however, make up the most important insect element in merlin diets. Again, the young birds in particular seem to favor these winged insects. Several authors have marveled at the flying skills demonstrated by young merlins hunting dragonflies and other insects (Lawrence, 1949; Street, 1960; Oliphant, 1974). Their twists and swoops almost resemble the flight of swallows (Hirundinidae), with the notable difference that merlins snatch insect prey with their feet.

At Cape May, New Jersey, large numbers of migrant merlins and dragonflies occurred on the same days. Investigation of 41 stomachs showed that these falcons had eaten more dragonflies than anything else (Allen and Peterson, 1936).

Merlin castings, or pellets, have been noted to contain disintegrated feathers, beetles, red bat fur, and avian bone chips. Thirty-three taiga merlin castings averaged 25 X 12 mm, tapering at one end (Johnson and Coble, 1967; Breckinridge and Errington, 1938).

Hunting behavior

Forest-nesting merlins occasionally do not hunt in their breeding territory, since they prefer more open hunting areas. Lawrence (1949) recorded eight passerines known to be merlin prey that nested safely in the immediate vicinity of a taiga merlin nest. Other small birds passed through the territory, sometimes very close to the nest, without incident. The breeding merlins also ignored small mammals, such as squirrels and chipmunks (Tamias sp.). Brown and Amadon (1968) suggested that merlins' aggressiveness toward common crows (Corvus brachyrhynchos) and other raptors near their nest might further benefit passerines nesting in the same area. In contrast, a male Richardson's merlin in Saskatoon pursued robins and house sparrows from his perch near the nest site, though he generally hunted at some distance from the nest (Oliphant, 1974).

Merlins commonly fly low over the ground when hunting, darting after prey with rapidly beating wings. These falcons will glide short distances, frequently rising and falling, but glide and hover less than many other falcons. On the attack, merlins fly at avian prey with a direct, very fast dash. If this first strike fails, they generally try a series of short, twisting stoops from above, shooting up after each attack for a few wingbeats and twisting into another stoop. When necessary, merlins follow prey into dense cover (Brown and Amadon, 1968; Fox, 1964; Lawrence, 1949). High-speed stoops from very high above prey, in the manner of the larger falcons, seem less common. Laing (1938) described a black merlin along the British Columbia coast which struck a black swift (Cypseloides niger) in a spectacular stoop. The Craigheads (1940) watched a taiga merlin take a tree swallow in similar fashion. Merlins hunting over water often pursue escaping prey high into the air in a ringing flight and then capture the prey in a high speed stoop as the victim tries to dive to cover (Temple, personal communication). McClure (1957) described a merlin in Japan that took a brown-eared bulbul (Ixos amaurotis) to the ground in a stoop and killed it with a bite at the base of the skull.

Blackbirds (Icteridae), starlings (Sturnus vulgaris), meadowlarks (Sturnella sp.), shrikes (Lanius sp.), and kingbirds all perch conspicuously in open places where merlins can strike from behind without warning. In the open, the slow flight of meadowlarks, as well as woodpeckers and flickers (Picidae), make them vulnerable to direct attack. In forests, merlins often concentrate hunting efforts on bright-colored and tree-nesting passerines. Merlins fly full-speed into flocks of ground-dwelling birds such as horned larks, but seldom make a second attempt if the first surprise attack fails. With enough room to gain top speed, mourning doves (Zenaida macroura), rock doves, and robins can outdistance merlins. Smaller, slower birds often escape by abrupt and agile dodging (Bond, 1936; Lawrence, 1949; Fox, 1964).

Courtship

Male merlins arrive on the breeding territory about a month before females. Most males arrive in April, but male Richardson's merlins may arrive back in Alberta and Saskatchewan as early as late February or early March. Further north, taiga merlins may not finish migration until May (Bent, 1938; Fox, 1964; Brown and Amadon, 1968; Lawrence, 1949; Fyfe, personal communication; Beer, 1966).

On arrival, males make a series of vocal flights from perch to perch. After the female's arrival, the male repeats this performance near her with a very distinctive fluttering flight. The wings beat very rapidly and the male calls while flying (see page 20 for description of call). Richardson's males have demonstrated this same flight pattern and call when flying to the female to copulate (Fyfe, personal communication; Brown and Amadon, 1968).

Female Richardson's merlins evidently do not solicit the males' attention. Males, in contrast, call and display both in and at the entrance to nests to attract the female to the nest. The male's display posture seems aimed at best presenting the blue back, upper wings, and head, and at the same time, the full tail pattern. Males accomplish this by bowing low and raising the tail, while at the same time spreading the tail and slightly raising the wings. In this way they present to the female an almost solid form of blue combined with the striking contrast of the tail bars. In a variation, the male presents to the female at one side or the other--usually the left--instead of head-on. From the side, the male varies his posture slightly, tilting to one side and raising the more distant wing above his body, thereby again presenting the back pattern to the female (Fyfe, personal communication).

Nest site fidelity and nesting density

Merlins use the same general area year after year for breeding, but not necessarily the same actual site, particularly if young were fledged the previous year (Brown and Amadon, 1968; Fox, 1964). Beer (1966) observed defending merlins around a single Minnesota nest in six out of fifteen years. Merlins nesting in Montana did not reuse the same nest, or nest grove, in successive years, although a successful 1974 fledging occurred 150 meters from a 1973 nest site (Ellis, 1974). In Newfoundland, one ground-nesting site on the side of a cliff was used continuously for 23 years (Temple, personal communication).

Nesting density is generally low--probably as a result of low merlin populations. The closest concurrent Richardson's merlin nestings found in Montana were 17 km. apart (Ellis, 1974), while three pairs of this subspecies nested in one 4.8-km. stretch of the North Saskatchewan River (Oliphant, personal communication). Craighead and Craighead (1940) found a concentration of merlins nesting on lakes on the Minnesota-Ontario border where nests were at least 3.2 km. apart. Raspberry Island, an 11.73-hectare islet off Isle Royale, Michigan, supported one pair of merlins and their two young; the adults hunted primarily in a spruce bog and along sheltered coves on the periphery of the island (Johnson and Coble, 1967). Lawrence (1949) estimated that a single pair of taiga merlins hunted in a circular area of 1.6 km. radius, with the nest at the center of the circle. In Saskatoon, a male hunted up to 3.2 km. from its probable nest (Oliphant, 1974).

Egg-laying and incubation

Merlins lay clutches of four to five eggs. Taiga merlins breeding in Newfoundland in 1969 averaged 4.3 eggs/clutch (N=15) (Temple, 1972c). Richardson's merlins on the Canadian prairie averaged 4.48 eggs/clutch, the mode being four and the range 3 to 7 (Fox, 1964). Montana prairie merlins laid five-egg clutches in two out of five nestings, and observers noted five young at another (Ellis, 1974). Second clutches of Richardson's merlins generally number only three eggs (Bent, 1938). Females lay eggs at two-day intervals (Fox, 1964, 1971; Brown and Amadon, 1968; Williams and Matteson, 1947; Eyre and Paul, 1973).

At the southern fringes of their range, merlins may lay eggs in early April (Brown and Amadon, 1968; Williams and Matteson, 1947). Egg-laying commences on the Canadian prairies during the first half of May, and peaks about May 20 (Fox, 1964; Oliphant, 1974). Taiga merlin eggs may be laid in late May or June (Brown and Amadon, 1968; Bent, 1938; Craighead and Craighead, 1940). Temple (1972c) found that 20 pairs of Newfoundland taiga merlins were incubating eggs between May 24 and July 9.

Merlin eggs vary in shape from short-ovate to oval to nearly elliptical-ovate. They look much like miniature peregrine falcon eggs. Egg ground color is cinnamon to light creamy buff, and is almost obscured by spots and blotches of burnt umber, chocolate, and red-brown. Occasional clutches are nearly white. Fifty Richardson's merlin eggs averaged 40.2 mm X 31.3 mm, with ranges of 37.0 - 44.5 X 30 - 33.5 mm. Sixty taiga merlin eggs averaged 40.5 mm X 31.4 mm, and ranged from 37 - 44.5 X 30 - 33 mm (Bent, 1938; Wolfe, 1946; Brown and Amadon, 1968). Prairie-nesting Richardson's merlins lay significantly larger eggs than other merlins (Temple, 1970).

Partial incubation begins before the female completes the clutch, and full-time incubation begins with the laying of the last egg. The female does most of the incubating, and the male most of the hunting, calling the female off to receive food. One male Richardson's merlin in Saskatoon assumed incubation duties whenever he brought food to the female, spending as long as two hours on the eggs while his mate fed (Oliphant, 1974). During incubation, male taiga merlins in Newfoundland flew from the nest about one-third of the times birds were flushed (Temple, 1972b). The Craigheads (1940) noted females sharing in hunting duties soon after the young had hatched. In observations of captive Richardson's merlins, only the female incubated (Fyfe, personal communication). Incubation lasts from 28-32 days (Fox, 1964; Brown and Amadon, 1968).

During the incubation period, the male supplies the female with food. She flies off the nest to receive prey, either on a perch or in the air. Oliphant (1974) noted that the female took prey in the air only after chicks hatched. Prior to hatching, she alighted on a perch facing the male and both grasped the prey in their beaks. After spreading their wings, pulling and calling softly, the male let go and the female flew to her favorite plucking perch.

Immatures can and perhaps regularly do establish territories and acquire mates. Three of 20 pairs of taiga merlins breeding in Newfoundland in 1969 contained males undergoing their first prebasic molt and not yet in definitive adult plumage; all three of these pairs fledged young (Temple, 1972c). Bent (1938) noted a breeding taiga female in immature plumage which had laid a full clutch of eggs.

Juvenile development

Young hatch at intervals. The eldest is markedly larger than the youngest, whose small size and lack of aggressiveness at feedings usually result in the smallest receiving the least food. Sixty-two percent of 21 taiga merlin nestlings were

female (Craighead and Craighead, 1940). Forty-eight percent of 30 Richardson's nestlings were female (Fox, 1964). Hatching occurs in Alberta and Saskatchewan in early June. In northern forests, taiga merlin eggs generally hatch in late June (Brown and Amadon, 1968; Lawrence, 1949; Fyfe, personal communication; Craighead and Craighead, 1940).

Adults may feed young on the first day out of the shell. Food provision consumes more and more time and energy of adults as the young quickly grow. For the first week or two, the female broods the young, receiving prey from the male on brief flights from the nest. Only the female has been noted brooding. Males or females may cache surplus prey on the ground or in tree cavities for future use. The male generally transfers avian prey to the female intact, who plucks it and often consumes the head. Females feed young birds small bits of food, and feedings increase in length from five minutes during the first week to as long as 25-35 minutes, later in the development of the young. Occasionally, the male plucks prey before transfer, and very rarely feeds the young himself--this last occurrence has been recorded only in taiga merlins in Minnesota by the Craigheads (1940). Taiga merlin females in Newfoundland often forced the male aggressively from the nest if he lingered after delivering food (Temple, 1972b). Even up to the time chicks are well-feathered, the female broods them at night. Daytime brooding continues until the chicks reach about two weeks of age (Lawrence, 1949; Selous, 1915; Breckinridge and Errington, 1938; Oliphant, 1974; Temple, personal communication; Brown and Amadon, 1968; Fox, 1964).

At hatching, the young are weak and immobile, their eyes closed. At three days of age they open their eyes. Activity increases steadily, until at 10 days active yawning and wing-flapping occur, while the primary and secondary sheaths become visible. Three 18-day-old young weighed about 165, 162, and 106 grams. At 18-20 days feathers cover almost all the down, wings are approaching full development, and the young falcons spend much time in preening, sometimes mutual preening. At this age, females may be separated from males by their larger feet and tarsi and bulkier form. At 25 days young beg food from their parents, "play" with nest mates, and sleep in the adult position (Fox, 1964; Brown and Amadon, 1968; Lawrence, 1949; Taylor, 1914).

Merlins fly at 25-35 days, averaging just about a month. Although they leave the nest at this time, their powers of flight are poor, amounting to little more than extended gliding. They remain dependent on their parents for food for several weeks as they perfect predatory and flying skills. Within a week after fledging, young take long training flights, and at the end of a second week can successfully catch insects. They remain in the general vicinity of the nest during these two

weeks. Dispersal begins soon after, until young birds reach complete independence at about five weeks after fledging (Fox, 1964; Eyre and Paul, 1973; Oliphant, 1974; Lawrence, 1949; Fyfe, personal communication; Brown and Amadon, 1968).

Territoriality and interspecific relations

Merlin eggs and nestlings occasionally fall prey to predators, but the adults' defense of the nest generally discourages territorial trespassers. Avian predation, however, could reach considerable proportions if parental behavior is seriously disrupted by pesticide residues (Fyfe, personal communication). Merlins usually drive away potential predators as soon as they penetrate the nesting territory, reacting when the invader is as much as .8 km. from the nest. Except for domestic dogs, and foxes in Newfoundland (Temple, personal communication), observers note merlins attacking only avian predators. Breeding and wintering falcons have chased red-billed tropicbirds (Phaethon aetherus), sharpshinned hawks, Cooper's hawks (Accipiter cooperii), broad-winged hawks (Buteo platypterus) and other buteos, golden eagles (Aquila chrysaetos), prairie falcons (Falco mexicanus), peregrine falcons, other merlins, American kestrels, great blue herons (Ardea herodias), gulls (Larus sp.), great horned owls (Bubo virginianus), crows, Clark's nutcrackers (Nucifraga columbiana), and common grackles (Quiscalus quiscula). Antagonism between merlins and any larger falcon seems to intensify if the larger bird took quarry; merlins seem particularly intolerant of accipiters (Fox, 1964; Lawrence, 1949; Bent, 1938; Oliphant, 1974; Fyfe, personal communication; Ellis, 1974; Allen and Peterson, 1936; Taylor, 1914). Migrating merlins frequently steal prey from flying kestrels and sharpshinned hawks by stooping at them and snatching the prey as the bird tries to defend itself (Temple, personal communication).

Merlins, in turn, may be harassed by other species. Bent (1938) notes an attack on an Alaskan merlin by seven black-billed magpies (Pica pica). Fox (1964) watched his captive male mobbed by a party of one robin, a pair of northern orioles (Icterus galbula), one common grackle, and several house sparrows. Other observers have seen robins attack merlins very aggressively (Fox, 1964; Lawrence, 1949). Hummingbirds (Trochilidae) consistently harassed Bond's (1936) trained female taiga bird, sometimes as many as 6 or 7 at once. On the breeding grounds, taiga merlins are often attacked by lesser yellowlegs (Totanus flavipes) if they approach the shorebird's nesting territory (Temple, personal communication).

Throughout their breeding range, merlins are notoriously bold, fearless, noisy, and aggressive in defending their nest from human intruders. All three subspecies consistently advertise

nest locations through aerial and highly vocal defense (Bent, 1938; Lawrence, 1949; Laing, 1938; Wolfe, 1946; Williams and Matteson, 1947; Craighead and Craighead, 1940; Ellis, 1974).

Generally the male merlin reacts to intruders first, flying out to scold them as far away as 1.5 km., and frequently at .8 km., from the nest (Ellis, 1974; Fox, 1964; Bent, 1938). Incubating or brooding females may remain silent on the nest under very close approach--less than 100 meters, or even until the observer begins to ascend the nest tree (Ellis, 1974; Bent, 1938). Once flushed, female merlins defend the nest more aggressively than males, in most cases (Fox, 1964; Lawrence, 1949; Craighead and Craighead, 1940).

Richardson's merlins defend their territory from the date of the male's arrival, peaking in intensity when the young are about two weeks old. Defensive behavior then diminishes rapidly until it disappears about one month after fledging (Fox, 1964).

One notable exception exists in this pattern of nest defense. Merlins nesting in densely populated areas of Saskatoon did not defend their nesting territory, but tolerated humans, dogs, cats, passing traffic, and large birds (including crows and gulls) without apparent concern or vocalization. Only when the nest tree was climbed to band the young, and when crows and grackles came within 6 meters of the nest, did the adults act defensively. These merlins did vocalize frequently when inspecting possible nest sites. At least one, and probably two, pairs of crows successfully reared young within 61 meters of one nest with very little interaction with the merlins.

An estimated 5,000 to 10,000 people passed within 15 meters of two of these nests while the merlins occupied them. The merlins may have adapted to their urban environment by limiting nest defense to the nest site itself to avoid spending literally all day in territorial defense--which would attract still more predators to the nest site (Oliphant, 1974). The contrast with parental behavior in all other merlin populations also suggests pesticide residues as a possible cause of the Saskatoon breeders' abnormal behavior (White, personal communication), though Fox (personal communication) reports that these birds lay eggs with thicker shells and lower residues than nearby rural populations. Oliphant (personal communication) has observed some successfully breeding pairs in Saskatchewan outside the city that have shown little aggression toward territorial intruders.

Vocalizations

The merlin's most frequently heard call is given during nest defense. Observers have variously described this as a harsh, loud, piercing, high-pitched "ki-ki-ki-ki-keeee" (Craighead and Craighead, 1940; Brown and Amadon, 1968; Oliphant, 1974); a "kla-kla-kla-kla-kla-kla," similar to the call of the American kestrel (Bent, 1938); or a "keeeyick-kyick-kyick-kyick-kyick" (Lawrence, 1949). Brown and Amadon (1968) attribute this "ki-ki-kiee" call to the male, and a lower-pitched "kek-ek-ek-ek-ek" to the female. Several other authors have described a "kek-ek" call, while not attributing it solely to the female (Craighead and Craighead, 1940; Bent, 1938). Oliphant (1974) noted that Richardson's merlins used this primary call during most male/female interactions, especially when the male brought food to the nest. A softer version of the call occurred when adults alternated incubatory duties or transferred prey while perched on a limb (see page 16 of this report). Female merlins have used the primary call while calling in fledged young to feed (Street, 1950).

In courtship flight, the male gives a "chrrrrr" call while flying. During copulation the call may be either this same "chrrrrr" or a slightly different and higher note. In displaying to the female at the nest, the male gives a high "chip, chip, chip" note which the female may answer (Fyfe, personal communication) (see also page 14). This "chip" note may be the same call described in males by Brown and Amadon (1968) as a thin, chirruping "chic-chic-chic" uttered more slowly than the rapidly repeated primary call, and by Bent (1938) in black merlins in their nest tree with fledged young: a plaintive whimpering not unlike the "kik-kik-kik" call of the flicker, but much more subdued.

In calling females off the nest to receive food, males may use a series of single, soft "chups" (Oliphant, 1974). In the same situation, the Craigheads (1940) noted a male to emit a call very similar to the long drawn out food cry of the peregrine falcon, but higher pitched. Females solicit food with an extended plaintive "eeep-eeep-eeep" (Brown and Amadon, 1968).

When the female feeds the young during the first week or two after hatching, and while she herself feeds, she emits a sharp "tick-tick-tick" or a series of "clicks," touching a chick's bill with a morsel of food at the same moment (Lawrence, 1949). The young, in turn, give a "keeyep-keeyep-keeyep" begging call (Lawrence, 1949; Brown and Amadon, 1968). Just prior to and after fledging, young merlins may emit a series of single rising notes, or "chees," especially at feeding times. Within a week

of fledging, the young birds space these single calls more closely, and begin to group them in calls more like those of adults (Oliphant, 1974).

Migration and wintering behavior

Richardson's merlins migrate a relatively short distance into the southern Great Plains; a smaller segment of the population winters on their northern plains breeding grounds. The black merlin resides semipermanently in the climatically stable coastal forests of the Northwest, and only a small portion of the population migrates south of their breeding range. Most taiga merlins, in contrast, are highly migratory. Western and central taiga-breeding birds migrate past Richardson's and black merlin populations in leapfrog fashion to winter in Central and South America. Eastern taiga birds also migrate far to the south, many individuals crossing the Gulf of Mexico to winter on the Caribbean Islands and in South America. A few taiga birds remain in the boreal forest all year (Temple, 1972a; Beer, 1966).

During fall migration, merlins tend to follow sea coasts, borders of streams and large lakes, and open country, preying on small birds also making their way south--although in Minnesota merlins seem to scatter, rather than follow well-defined migration routes (Brown and Amadon, 1968; Bent, 1938; Beer, 1966). Fall migration is much more conspicuous than the return trip northward in spring (Brown and Amadon, 1968; Bent, 1938). Along the New Jersey coast, taiga merlins (along with kestrels and peregrines) wander southward over salt meadows in preference to wooded areas favored by migrating accipiters (Allen and Peterson, 1936). At Fishers Island, New York, they favor flying on a southwest wind (Bent, 1938). Merlins fly rather high, sometimes in large straggling flocks (Brown and Amadon, 1968). In Washington, migrant black merlins prefer open country and tidal flats along Puget Sound in both fall and early spring (Bent, 1938). Some merlins in Alaska migrate along the Alcan Highway, perhaps to take advantage of the abundant food in the open pathway through the forest, for thousands of Lapland longspurs (Calcarius lapponicus) migrate along this same route (White, 1969).

Immature merlins generally migrate before adults, leaving breeding grounds about one month to six weeks after leaving the nest (Bent, 1938; Brown and Amadon, 1968). Young Richardson's merlins drift southward from Saskatchewan in mid-August (Fox, 1964), about as early as any merlins in North America. Migration peaks between mid-September and mid-October in most areas. Nearly all merlins have left the northern fringes of their range by September 15; migration peaks in Minnesota during the second and third weeks of September, in South Carolina in October (Brown and Amadon, 1968; Beer, 1966; Bent, 1938). Most

Richardson's merlins arrive on their eastern Colorado wintering grounds by the last two weeks of October; immatures migrate farther south than adults--as far as Arizona and New Mexico, rather often. More adults remain on the Canadian prairies through the winter (Fox, 1964; Bailey and Niedrach, 1965).

Some wintering birds seem to wander at random; others stay for some time at a location (such as an urban area) that provides abundant prey (Fox, 1964; Oliphant, personal communication). The three races may mingle in winter quarters (Eyre and Paul, 1973; Brown and Amadon, 1968).

In spring, most merlins pass northward through central North America in March (Brown and Amadon, 1968; Fox, 1964; Williams and Matteson, 1947). Most taiga-bound birds pass through northern Minnesota in April (Beer, 1966). The very last to leave the more southern winter ranges head north in late March and early April (Bent, 1938).

Productivity

Productivity in North American merlin populations has declined significantly in the past 20 years. Prior to about 1950 (and prior to the widespread use of persistent organochlorine pesticides), merlins across the continent hatched more young per nest than they have since that date.

The mean clutch of merlins has varied little since the first data were recorded. The number of young hatched per nest in the northern Great Plains prior to 1950 averaged 4.3 (N=3), from a mean of 4.7 eggs/nest (N=10) (Fox, 1971). In eastern Canada, taiga merlins laid 4.2 egg clutches (N=18), and hatched 3.8 young per nest with young (N=15) prior to 1947 (Temple, 1972c).

Eastern taiga birds have suffered lower productivity since those years. From 1950-1969, these merlins laid average clutches of 4.5 (N=2), from which they hatched only 2.2 young per nest with young (N=6); hatching success totaled 48%, down from almost 91% prior to 1947 (Fox, 1971; Temple, 1972c). Newfoundland merlins in 1969 laid clutches averaging 4.3 eggs (N=15), and hatched 3.0 young per nest with young (N=19) (Temple, 1972c). Although these Newfoundland birds reached only 70% hatching success, they fledged young in 95% of 20 nests. Central and northern forest-breeding birds have maintained the highest productivity of any North American merlins in recent years. From 1960-1969, northern taiga merlins laid 4.5 eggs/nest (N=2), hatching 4.0 birds per nest with young (N=5)--a hatching success of 89% (Fox, 1971). Merlins breeding in forested areas of the Great Plains maintained good production

of young from 1950-1969, laying 4.1 eggs/nest (N=9), and hatching 98% of these--4.0 young per nest with young (N=16) (Fox, 1971). Only one of two taiga merlin nests recently found in Alaska fledged young, but this single nest fledged five birds (Adolphson, 1969).

Richardson's merlins nesting in the Great Plains have decreased more alarmingly in productivity. Fox (1964) found that 10 pairs of Saskatchewan-nesting merlins laid an average of 4.5 eggs/nest. Hatching success, 91% prior to 1950, decreased to 60% for these birds, which hatched 2.7 young per nest with young. Fledging remained good, however, with 2.6 young fledged per nest. Most disturbing, though, is the fact that this population of merlins ceased to breed soon thereafter (Fox, 1971). Hatching success throughout the Great Plains from 1950-1969 averaged 49% (Fox, 1971). Richardson's merlins breeding in Montana laid clutches of five eggs, but hatched only 3.2 young per nest with young (Ellis, 1974). They fledged 3.2 birds per nest with fledglings; 57.1% of seven nests fledged young. Hunter (1967) reports that three merlin nests in South Dakota all failed to fledge young. Five of eight (62.5%) Saskatoon nests fledged young; all five fledged 4-5 young (Oliphant, 1974).

These data indicate decreasing productivity in North American merlin populations. Fyfe (personal communication) attributes lowered Richardson's merlin productivity primarily to desertion during incubation and failure of incubated eggs to hatch. Temple (1972c) believed that problems in Newfoundland were probably due to increased egg loss and decreased hatchability. Broken eggs and adult mortality resulted in 2 out of 3 nest failures in Montana (Ellis, 1974).

Pesticide relationships

Research has linked decreased reproductive success and population declines in bird-eating raptor populations to accumulation and concentration of chlorinated hydrocarbon pesticide residues through the food chain. Zarn (1974) has reviewed briefly the effects of DDT and other organochlorine pesticides on raptors. Aberrant behavior and eggshell-thinning seem the most conspicuous symptoms of pesticide poisoning. Specifically, chlorinated hydrocarbons seem to inhibit carbonic anhydrase activity in the shell gland, resulting in decreased calcium carbonate deposition in the shells of developing eggs, and consequently, thinner-shelled eggs.

Merlins, like other bird-eating falcons, are suffering reduced productivity probably resulting from accumulation of pesticide residues. The lipid of four adult merlins migrating along the

western shore of Lake Michigan contained an average of 302 ppm DDE, and 196 ppm PCB compounds (polychlorinated biphenyls). DDE accounted for 96% of all DDT residues in the birds. The lipid of three immature merlins contained 50.3 ppm total DDT, of which 49.3 ppm was DDE. PCB's averaged 28.6 ppm. All but one of the merlins biopsied (both adult and immature) contained more DDE than PCB's. Peregrines trapped here showed the reverse ratio. Pesticide fallout must evidently vary in the areas of boreal forest and tundra where these two migrants respectively breed (Risebrough, et al., 1970). These figures may be compared to DDE figures for lipids from adult peregrines from the MacKenzie River region (Enderson and Berger, 1968) and from Alaska (Cade, et al., 1968) of 392 ppm and 725 ppm, respectively. The merlins have almost the same level of contamination as the peregrines, and might therefore be expected to show eggshell thinning.

Fox (1971) calculated eggshell weights for 51 merlin eggs collected from 1890 to 1969. From 1890 to 1949, eggshells from Great Plains and taiga-breeding birds did not differ significantly and averaged about the same through those years--1.71 grams. From 1950-1969, merlin eggshells averaged 1.31 grams, a 23% decrease. This decrease resembles those reported by Hickey and Anderson (1968) for declining bald eagle (Haliaeetus leucocephalus) and osprey (Pandion haliaetus) populations and extirpated peregrine falcon populations in the United States. Fox (personal communication) studied 40-50 pairs of Richardson's merlins nesting in Alberta in 1974, and judged reproductive success 40-50% of that prior to pesticide use, while eggshells averaged 15-20% thinner and pesticide residues proved high. Swartz (personal communication) has noted high pesticide residues and eggshell thinning in eggs from interior Alaskan merlins, although productivity appears fairly normal.

Merlins breeding in Newfoundland contained 267 ppm (dry weight basis) DDE, while five unhatched eggs averaged 40.4 ppm (dry weight basis) DDE (Temple, 1972c). These residue counts are lower than the breeding peregrines and their eggs and lower than the Lake Michigan migrant merlins. No marked delay in the breeding cycle of the Newfoundland merlins has occurred, nor has clutch size decreased significantly since pre-pesticide times. Eggshells, however, have decreased 9% in thickness, a decrease accompanied by reduced productivity.

In Montana, residues (wet weight basis) in 3 non-viable eggs from one Richardson's merlin nest averaged 9.4 ppm DDE, 8.0 ppm dieldrin, and 5.6 ppm heptachlor epoxide. PCB's, toxaphene, and other chlorinated hydrocarbons were undetected (Ellis, 1974). Only one egg contained a dead embryo. Pesticide residues calculated on a dry weight basis are roughly comparable to 5x the

level calculated on wet weight basis; lipid fractions are about 17-20x wet weight (Fox, personal communication). DDE residue levels in these Montana eggs thus are similar to DDE levels in Temple's (1972c) Newfoundland eggs. But the Montana merlins suffered considerably more nest failures--3 out of 7 as compared to 1 out of 20 in Newfoundland. Embryonic mortality, in contrast, was high in the Newfoundland population: all five unhatched eggs collected for residue samples contained dead embryos.

HABITAT REQUIREMENTS

Breeding requirements

Taiga merlins breed in the boreal forest, and within this biome choose somewhat open territories, such as forest edges, lake shores, bogs, etc. These merlins generally nest adjacent to water. All nests described from northern Minnesota were in conifers near the edge of large lakes, many on islands in the lakes (Beer, 1966). In denser areas of the boreal forest, taiga merlins usually nest in abandoned crow or common raven (Corvus corax) nests in coniferous trees. Trees utilized include many dominant boreal species: black spruce (Picea mariana), red spruce (Picea rubens), white spruce (Picea glauca), eastern white pine (Pinus strobus), jack pine (Pinus banksiana), etc. Along the northern edge of their range, on the fringes of the tundra, they often nest under tree branches in a scrape on the ground (Temple, personal communication; Fyfe, personal communication; Johnson and Coble, 1967; Bent, 1938; Craighead and Craighead, 1940; Lawrence, 1949).

Taiga merlins may reline the nest with some combination of small twigs, pieces of bark, feathers, grass, soft rootlets, and conifer needles. They nest almost anywhere in trees, from 1.5 meters above ground to the top of 18-meter spruce, usually very close to the trunk. Taiga merlins also have nested in tree cavities, under the roofs of deserted buildings, and on cliff ledges in nests made of bits of rock (Bent, 1938; Craighead and Craighead, 1940; Fox, 1964; Williams and Matteson, 1947; Lawrence, 1949).

Few nests of the black merlin have been described in detail. These merlins breed in moist Pacific coastal forests, probably in areas similar to the open habitat favored by taiga merlins in boreal forest. Most observed nests of F. c. suckleyi have been very high in conifers in dense coastal stands of Douglas fir (Pseudotsuga menziesii), Sitka spruce (Picea sitchensis), western hemlock (Tsuga heterophylla), Pacific silver fir (Abies amabalis), and western redcedar (Thuja plicata). Both stick-nests and cavity-nests are known. Black merlins frequently nest near large lakes (Temple, personal communication; Laing, 1938; Bent, 1938).

Richardson's merlin breeds only in the prairie-parkland of the northern Great Plains. Within this biome, the subspecies seems to prefer isolated groves of trees with open prairie surroundings, mixed woods, and wooded areas along prairie river banks and islands (Temple, personal communication; Fyfe, personal communication; Fox, 1964).

F. c. richardsonii tend to breed where native grassland provides adequate prey species, and quaking aspen (Populus tremuloides) or other trees provide suitable nesting habitat. On the Saskatchewan-Alberta prairie they prefer to nest in deserted farmstead shelterbelts and groves of deciduous trees where farmland has gone back to grassland. The merlins choose trees spaced well apart whose lower 2.4 or 3 meters have been rubbed bare of branches, and where undergrowth has been trampled and destroyed by cattle. This appears to be a temporary stage in the total destruction of trees by cattle, and the number of sites that fit this description is steadily decreasing. Fox (1964) found about half of 25 nests in Saskatchewan within .8 km. of water. He also noted that water may be utilized by merlins for bathing. Captive merlins have been known to bathe in water, although Wing (1950) observed a wild merlin dust bathing (Fyfe, personal communication; Fox, 1964, 1971).

In southern areas of the open grassland, Richardson's merlins nest most frequently in deserted crow and magpie nests, and seem to have a preference for the latter (Fyfe, personal communication). Ninety-two percent of Fox's (1964) nests were old nests of these two species. On the same Saskatchewan study area, 21 of 25 merlin pairs nested in deciduous trees: aspen, poplar (Populus sp.), box elder (Acer negundo), willow (Salix sp.), and birch (Betula sp.). The key determinant is the nest rather than the species of tree: in areas where crows and magpies nest in conifers, merlins will then nest in these nests. All of seven Richardson's merlin nests on the Montana prairie were in groves of conifers--Douglas fir, ponderosa pine (Pinus ponderosa), and limber pine (Pinus flexilis)--near flat or rolling grassland. All these merlins nested in old corvid nests--six of them magpie nests (Ellis, 1974).

The prairie subspecies occasionally nests in tree cavities and in old magpie nests placed in holes in cliffs (Fyfe, personal communication). Nests are usually lined with dry inner bark of poplar (Bent, 1938). Seven of eight Richardson's merlin pairs in Saskatoon nested high in large spruce, with tall deciduous trees nearby, always in what appeared to be an old crow's nest. Two pairs nested in highly populated areas within about 30 meters of major roads with heavy traffic (Oliphant, 1974).

No observers have recorded Richardson's merlins nesting on the ground, a most important fact considering the serious shortage of suitable nest trees in the subspecies' range. A shift in nesting patterns to include ground-nesting would greatly increase habitat available for this bird (Fyfe, personal communication), though predator pressure would also increase (Ellis, personal communication).

Wintering requirements

Wintering taiga merlins tolerate an amazing range of habitats--from beaches, dunes, and swamps to tropical forests and scrub, to farmland and urban areas. Black merlins also range through a variety of habitats on their wintering grounds--desert scrub, coastal forest, coniferous forest, farmland, and urban areas (Temple, personal communication).

Richardson's merlins, on the other hand, seem more selective in choosing wintering grounds, preferring prairie habitat with scattered trees, utility poles, or other hunting perches--habitat very similar to their breeding habitat (Temple, personal communication). Fence posts and lower perches attract the falcons even where telephone poles are available (Fox, 1964). Wintering Richardson's merlins favor winter wheat stubble in Wyoming, and in Colorado prefer very open country on the plains or land along or near creek beds overgrown with cottonwoods and willows (Fox, 1964). In Utah, where all three subspecies winter, Richardson's merlins occur with greatest frequency in open farmland; the other two subspecies show no strong habitat preference (Eyre and Paul, 1973). In northern parts of its wintering range, Richardson's merlin also frequents urban areas; many immature birds, for example, winter in Saskatoon (Temple, personal communication; Fyfe, personal communication; Oliphant, 1974 and personal communication).

LIMITING FACTORS

Three factors presently limit merlin populations. Two are components of the environment required for successful reproduction: first, an adequate food base and second, available, and suitable, nest sites. The third factor exists in varying strength, and results in varying decreases in productivity: pesticide residues (Fyfe, personal communication).

Habitat destruction

Habitat destruction to date is of minor importance for taiga and black merlins. Hence, their supplies of food and nest sites remain adequate (Fyfe, personal communication; Temple, personal communication). This is not true for Richardson's merlins, however.

An adequate food base for prairie merlins means an adequate supply of grassland birds--which can only mean uncultivated grassland habitat. Without native grassland, there will be few Richardson's merlins (Fyfe, personal communication). Likewise, destruction of habitat reduces the number of adequate nest sites--which, for this subspecies, are narrowly defined. Fox (1971) documents a steadily decreasing number of suitable nest trees on the Saskatchewan prairies. Merlins have ceased breeding entirely in some areas of intensive cultivation (Fox, personal communication). Habitat destruction continues to accelerate as more and more land goes under intensive agriculture, putting ever greater pressure on merlins of the prairies.

Chemical contamination

Merlins are carrying high pesticide residue levels--organochlorines, mercury, and PCB's (Fyfe, personal communication). Thin-shelled eggs and poor overall productivity have been noted in varying degrees throughout the range of the species. Richardson's merlins, however, breed in the most contaminated habitats and predictably their reproductive success has decreased drastically over most of their range. Pesticide contamination may be the single biggest problem facing North American merlins (Temple, personal communication; Fox, personal communication).

Little seasonal variation exists in the pesticide content of merlin diets, since most of these falcons prey on the same species on both breeding and wintering grounds (Temple, personal communication). Migration patterns in prey species can, however, dramatically affect pesticide levels in prey and predator. In Newfoundland, brain tissue of resident gray jays contained only .24 ppm (dry wt. basis) DDE, while brains of migrant robins and Savannah sparrows contained 3.17 ppm and 2.10 ppm, respectively. These three species accounted for the bulk of the breeding merlins' diet (Temple, 1972c).

Other mortality factors

Several specific merlin mortality factors have been noted. Nestlings or eggs may not survive bad storms (Oliphant, 1974), and may also succumb to disease or parasites, such as Simulium flies (Ellis, 1974). Adults and young may catch fatal Trichomonas gallinae (frounce) from consuming infected doves (Stabler, 1969). Before protective legislation, merlins were often shot; they allow a close approach when perched and will fly quite near a man in the open (Bent, 1938; Lawrence, 1949; Jewett, 1948). Temple (personal communication), however, feels that shooting no longer poses a serious threat to the species,

at least as indicated by banding recoveries. Merlins have also been known to die on impact with windows in cities (Porter and Knight, 1952).

Museum specimens of Richardson's merlins examined by Fox (1964) showed a decrease in the ratio of subadults to adults from 60% in August to 30-40% in January, when molt begins. Over 70% of total returns for merlins banded as nestlings occurred during their first year of life.

Human interaction with nesting merlins may have serious and harmful effects on reproductive success. Oliphant (1974) believed that two Saskatoon Richardson's merlin nests may have failed because the nest tree was climbed during the early stages of incubation. As far as he knew, no successful nest was climbed prior to hatching. Temple, Fox, and Ellis all climbed nests which were ultimately successful, however (Ellis, personal communication). Bent (1938) notes that if the nest of a Richardson's merlin is climbed before an egg is laid, the adults will always desert the nest, though merlins do not desert easily after the clutch is complete (Fox, personal communication). In contrast, a pair of taiga merlins moved their nest and two eggs some 36 meters after two near misses by observers attempting to collect the adults as specimens (Bent, 1938).

Falconers trap numbers of merlins annually, and have definite impact on the population of the species. Such impact may prove positive, since some trapped birds are used in captive breeding projects. But as the species decreases in abundance, the negative impacts of trapping birds from the wild increase.

SPECIES AND HABITAT MANAGEMENT RECOMMENDATIONS

1. We know little of merlin distribution, breeding behavior, habitat requirements, or reproductive success in Alaska. We know virtually nothing about black merlin ecology. Breeding population surveys, as well as any black merlin research, are essential before we have the basic data necessary to formulate management plans. Merlins in Alaska, although reproducing adequately now, as far as we know, should be watched very closely. Development of the state's resources has increased sharply in pace, and wilderness country has begun to shrink. Merlins no longer remain isolated from the drastic changes in habitat wrought by man. Managers of public lands have an enormous responsibility to carefully consider the effects of each of their decisions on merlins, as well as on all wildlife species.

2. Ban, or at least severely limit, use of persistent pesticides in North America and in Central and South American wintering areas.

3. In the northern Great Plains, habitat management for Richardson's merlins seems possible. First, land managers should give careful consideration to preservation of native prairie whenever development alternatives exist. BLM-administered public lands as well as National Grasslands, National Wildlife Refuges, and National Parks and Monuments, are prime candidates for preservation of grassland habitat. Without the native grassland, the merlins' food base will disappear, along with the merlins themselves soon after (White, 1974).

   Merlin nesting sites should also be provided both on grassland preserves and on other managed grasslands. Scattered small groves of trees managed for merlin nest sites would benefit the falcon, even in agricultural areas and on wintering grounds (Temple, personal communication). Construction of artificial nest sites, as described for ferruginous hawks (Buteo regalis) in Olendorff, 1973, should also be investigated. Anywhere in the northern plains where such management occurs, even though perhaps not presently within the Richardson's merlin breeding range, could prove valuable for the falcon if it shifts its range slightly to adapt to the change in habitat.

   White (personal communication) has pointed out that such shifts in range can indeed take place. Observers in Utah collected one probable Richardson's merlin about 1870, but from 1920-1960 only non-richardsonii were seen and collected in the state. In about the mid-1960's, Richardson's merlins suddenly increased in frequency in the state, until today (1975) about half of the eight to ten merlins trapped annually along the Wasatch front are F. c. richardsonii.

   Fox (personal communication) believes that Richardson's merlins have already begun to shift their range in response to increased cultivation and habitat loss in rural Saskatchewan and Alberta, and cites recent nestings in Saskatoon, Edmonton, Montana, and Wyoming are evidence. He predicts an increase in Montana, Wyoming, and North and South Dakota nestings.

4. Carefully regulate capture of merlins for falconry purposes.

PROTECTIVE MEASURES INSTITUTED

A. Legal or regulatory

   1. Regulations administered by the U. S. Environmental Protection Agency limiting the use of DDT and other persistent pesticides within the United States should

benefit merlins by reducing pesticide burdens in merlin prey. Similar regulations are also in effect in Canada.

2. On March 10, 1972, the United States and Mexico added merlins to the list of bird species protected by the convention for the Protection of Migratory Birds and Game Mammals, originally ratified on February 7, 1918.

B. Captive rearing

One method of protecting species endangered by pesticide-contaminated environments is to maintain the species in captivity until the environment becomes safe, and reintroduction is possible. Merlins bred successfully in captivity for the first time in 1974. The following list details recent captive merlin breeding projects:

1. John Campbell, of Black Diamond, Alberta, raised four young merlins in 1974--the first successful captive rearing of the species (Fyfe, personal communication; Swartz, personal communication).

2. In 1974, Richard Fyfe's (Edmonton, Alberta) captive merlins laid fertile eggs, but they didn't hatch; those eggs left with the females (rather than placed in an incubator) disappeared, perhaps eaten by the adult falcon (Fyfe, personal communication).

3. L. G. Swartz, at the University of Alaska, had a near-miss in 1969, when his female merlin died with a full clutch of five eggs "on the way" (Swartz, 1972).

4. Two other captive breeding projects in the United States have not been successful to date. The first is run by a private individual in California. The second, the U. S. Fish and Wildlife Service project at Patuxent, Maryland, has succeeded in getting fertile eggs, though none have hatched (Fyfe, personal communication).

CURRENT RESEARCH

Richard Fyfe and his coworkers of the Canadian Wildlife Service conduct merlin research in western Canada. Their work has emphasized Richardson's merlins, but concerns taiga merlins as well. They have considerable data on merlin courtship and breeding biology, population changes and habitat degradation, and residue levels (Fyfe, personal communication). L. W. Oliphant (Dept. Vet. Anat., Coll. West. Vet. Med., Univ. of Sask., Saskatoon) has recently received funds to conduct merlin research in the Saskatoon area (Oliphant, personal communication).

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SUMMARY

Merlins, small swift-flying falcons, range through much of the northern hemisphere. Three subspecies breed in North America, each in an ecologically distinct region. Male merlins have blue-gray dorsal plumage, females brownish plumage. Immatures resemble adult females. Merlins average 25 to 34 centimeters long, with a wingspread of about 60 cm. Small size, a distinctly banded tail, dark dorsal plumage, and indistinct facial markings distinguish merlins from other falcons.

Falco columbarius columbarius, the taiga merlin, breeds in the boreal forest from Alaska to Newfoundland, and winters south to South America. F. c. richardsonii, the Richardson's merlin, breeds in the prairie-parkland of the northern Great Plains, wintering mostly in Colorado and Wyoming. The black merlin, F. c. suckleyi, resides semipermanently in the moist coastal forests of western British Columbia, and perhaps, Washington and southeast Alaska. Some black merlins winter south as far as California and New Mexico.

All North American merlins have recently decreased in reproductive success. Organochlorine pesticide residues have contributed to these decreases. Intensive agriculture has decreased both the native grassland necessary to support the food base of Richardson's merlins and the number of suitable nest-trees. Taiga and black merlins, as well, face habitat destruction as man develops the natural resources of the northern forests.

Merlins hunt diurnally, occasionally into twilight. They consume birds, almost exclusively, with insects a minor, but significant, part of their diet. Mammals are taken occasionally. Merlins hunt avian prey ranging in size from sparrows to ptarmigan. They attack with a direct, very fast dash, but also may stoop from high above prey.

Most males arrive on the breeding territory in April, about a month before females. Males display to females during courtship. Merlins generally do not nest in the same site in successive years, but may nest in the same area. Nesting density is low.

Merlins lay clutches of four or five eggs from April to July, mostly in May. Females do most, and usually all, of the incubating. Incubation lasts 28-32 days. Males provide food for the incubating female, and later the young as well. Males, however, rarely feed the young. Young merlins fledge at about one month of age. About five weeks later they reach full independence.

Nest defense by adults discourages most predators. Merlins react very aggressively to large birds and raptors near their nests, as they do to human intruders. Some merlins nesting in urban environments refrain from such aggressive nest defense. Merlins vocalize often when breeding, using their primary nest defense call most frequently.

Fall migration is much more conspicuous than spring migration. Migration southward peaks between mid-September and mid-October. In spring, most merlins pass through central North America in March.

Productivity has declined significantly in North American merlin populations during the past 20 years. Desertion during incubation, and increased egg loss and decreased hatchability seem the major problems. These all derive primarily from organochlorine pesticide residues in breeding merlins, resulting in eggshell thinning, dead embryos, and aberrant parental behavior.

Taiga merlins breed in open areas of the boreal forest, usually in abandoned corvid nests in conifers, but occasionally on the ground. Taiga merlins usually nest near water. Black merlins favor open habitat in the Pacific coastal forests, nesting very high in conifers. Richardson's merlin breeds in old corvid nests on the prairie-parkland, in deciduous trees or conifers--wherever the crows and magpies choose to build nests. Suitable nest sites for Richardson's merlins on the Canadian prairies are diminishing fast in number. Richardson's merlins do not nest on the ground, an adaptation which would greatly expand suitable habitat.

Wintering taiga and black merlins tolerate a wide variety of habitats. Richardson's merlins have narrower tolerance for wintering grounds, seeking open farmland and prairie similar to their breeding habitat.

Three main factors limit merlin populations: availability of nest sites, adequacy of the food base, and pesticide residue levels. All three subspecies depend on these same factors, but Richardson's merlin populations have been most pressured, and therefore are in the greatest trouble. Other mortality factors (disease, weather, etc.) are not as immediately important. Nests may fail, however, if the nest tree is climbed during incubation.

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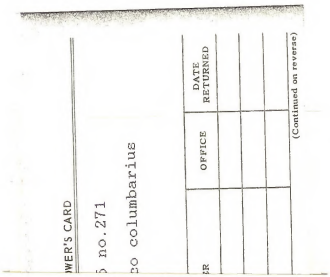

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